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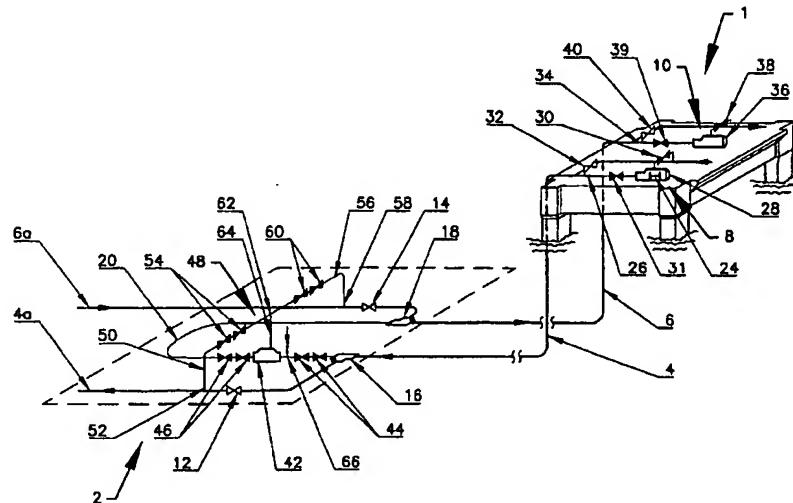
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(54) Title: PIGGING METHOD AND APPARATUS



(57) Abstract: A method of pigging a pipeline network (4,6) connecting a host facility (1) to a remote location (2), the network including a delivery pipeline (4) for transporting a first fluid from the host facility (1) to the remote location (2) and a return pipeline (6) for transporting a second fluid from the remote location (2) to the host facility (1), the method comprising the steps of: (i) propelling a pig (24) with a first fluid along the delivery pipeline (4) to the remote location (2); (ii) capturing the pig (24) in a pig trap (42) situated in a pig transfer pipe (20) connecting the delivery and return pipelines (4,6); (iii) diverting the second fluid to propel the pig (24) out of the pig trap (42) and around the transfer pipe (20) into the return pipeline (6); and (iv) propelling the pig (24) with the second fluid along the return pipeline (6) to the host facility (1).

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PIGGING METHOD AND APPARATUS

The present invention relates to the pigging of pipelines, that is the propelling of a device known as a pig through a pipeline.

Pigging may be required for a number of reasons including removal of fluid from a pipeline, measuring the internal diameter or thickness of the pipeline and the removal of deposits such as wax and scale. These operations are particularly relevant in the field of hydrocarbon liquid and/or gas extraction from sub-sea deposits since long pipelines often extend from a host facility, usually afloat or on shore, to a remote sea-bed location. The pigs are commonly propelled along a pipeline to be pigged by means of fluid pressure and are launched from a pig launcher at the host facility and trapped at the remote location. The necessity to trap the pigs in this manner and then arrange for their retrieval adds undesirably to the cost of construction and operation. If alternatively the pigs are launched from the remote location, the difficulty of delivering them to the remote location and inserting them into the pipeline causes a problem. A method referred to as round trip pigging (detailed below with reference to Figures 1 and 2) has been employed in which a pig piping loop is installed linking two pipelines and valves are provided for selectively placing the remote ends of the two pipelines in communication with each other via the pig piping loop. A pig can be propelled down a first of the two pipelines, by means of a first fluid flowing therethrough, round the pig piping loop and back up the second of the two pipelines by means of a diverted flow of the first fluid. This system suffers from two

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major drawbacks. Firstly, normal flow of first and second fluids through the first and second pipelines respectively is cut off for the duration of the pigging process because flow of the first fluid is used to not only propel the pig to the remote location but also propel it back up the second pipeline to the host facility. If the second pipeline is a production pipeline, normally delivering hydrocarbon fluids from a well or wells, the well(s) will need to be shut in and restarting a well can be problematic. A second problem with the above system is that, if the first and second fluids are not compatible with each other, e.g. because of a chemical reaction or because of potential contamination, round trip pigging as described above may not be possible. One possible way round this contamination problem is to replace each pipeline with two parallel pipelines of smaller diameter in order that a pig can be driven down one and back up the other. This adds undesirably to the cost of pipework and still does not avoid the problem of interrupting flow through the pipeline(s) during the pigging process.

An object of the invention is to provide a pigging method and apparatus which overcomes at least one of the above problems.

Thus according to the invention there is provided a method of pigging a pipeline network connecting a host facility to a remote location, the pipeline network including a delivery pipeline for transporting a first fluid from the host facility to the remote location and a return pipeline for transporting a second fluid from the remote location to the host facility, the method comprising the steps of:

- (i) propelling a pig along the delivery pipeline

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from the host facility to the remote location by means of the first fluid;

(ii) capturing the pig in pig capture and transfer means at the remote location;

(iii) transferring the pig to the return pipeline by means of the pig capture and transfer means; and

(iv) propelling the pig along the return pipeline from the remote location to the host facility by means of the second fluid.

Using the method according to the invention the flows of first and second fluids to and from the remote location need not be substantially interrupted by the complete pigging cycle since flow of the first fluid through the delivery pipeline delivers the pig to the remote location and flow of the second fluid propels the pig along the return pipeline to the host facility. Accordingly, in a hydrocarbon field in which one or more injection wells are being supplied with a first fluid (e.g. injection water) via the delivery pipeline and a second fluid (e.g. oil or gas from one or more production wells of the field) is supplied to the host facility via the second pipeline, the field does not need to be shut in and the consequent problems associated with restarting the well or wells are avoided. Furthermore, since the first fluid is not used to propel the pig along the return pipeline, contamination of the return pipeline with fluid from the first pipeline can be at least substantially avoided.

Preferably the flows of first and second fluids are substantially uninterrupted.

For minimising contamination of the return pipeline with

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the first fluid, preferably transferring of the pig to the return pipeline is effected by means of the second fluid.

Preferably the transferring of the pig to the return pipeline is effected via a pig transfer piping loop and in order that fluid used to transfer the pig to the return pipeline can freely enter that piping loop, a flow of the second fluid is preferably diverted from the return pipeline via a return bypass pipe to propel the pig through the pig transfer piping loop.

Conveniently an inlet of the return bypass pipe is connected to the return pipeline at a location upstream of a junction between the return pipeline and the pig transfer piping loop.

In order to provide precise positional control over the pig during the transfer process, advantageously capturing the pig involves capturing the pig in a pig trap in series connection with the pig transfer piping loop.

Since the pig is propelled to the pig transfer piping loop by means of the first fluid, preferably capturing the pig in the pig trap includes diverting a flow of the first fluid through the pig trap. Conveniently this diversion involves passing a flow of the first fluid through a delivery bypass pipe with an outlet connected to the delivery pipeline at a location downstream of a junction between the delivery pipeline and the pig transfer piping loop.

Since valves are customarily incorporated in such pipes/pipelines for controlling flow of fluids to and from

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a well or wells connected to the remote location, the steps of the method are preferably effected by selectively opening and closing valve means situated in the pipes/pipelines.

At least a majority of the first fluid may be water or a gas and at least a majority of the second fluid may be a hydrocarbon liquid or gas from a hydrocarbon well. The first or delivery fluid and the second or produced fluid may however comprise fluid or fluid mixtures other than water or hydrocarbon liquid or gas.

When contamination of the return pipeline with the first fluid must be completely eliminated, the method preferably includes the step of flushing the first fluid from the pig trap with a flushing fluid which may comprise either the second fluid or a third flushing fluid supplied for example from an injection pipeline.

The method may involve propelling the pig via two or more remote locations between propelling the pig from and to the host facility.

According to a second aspect of the invention there is provided pipeline pig capture and transfer apparatus for installation at a location remote from a host facility for capturing a pig delivered to the remote location from the host facility through a delivery pipeline carrying a first fluid and transferring the pig to a return pipeline carrying a second fluid for delivery therethrough back to the host facility, the apparatus including a pig transfer piping loop connecting a delivery pipeline junction with a return pipeline junction and a return bypass pipe

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connected to divert a flow of the second fluid from the return pipeline for propelling the pig through the pig transfer piping loop and into the return pipeline.

Preferably an inlet of the return bypass pipe is connected to the return pipeline at a location upstream of a junction between the return pipeline and the pig transfer piping loop.

A pig trap is preferably provided in series connection with the pig transfer piping loop and an outlet of the return bypass pipe is conveniently connected at or upstream of the pig trap.

So as to propel the pig into the pig trap, preferably the apparatus further includes means for diverting a flow of a first fluid from the delivery pipeline through the pig trap and back into the delivery pipeline.

Preferably the diverting means includes a delivery bypass pipe with an outlet connected to the delivery pipeline at a location downstream of a junction between the delivery pipeline and the pig transfer piping loop.

An inlet of the delivery bypass pipe is preferably connected at or downstream of the pig trap.

The apparatus preferably includes valve means situated in the pipes/pipelines for controlling fluid flows therethrough. Preferably the apparatus includes at least one valve in the or each transfer pipe for isolating the pig trap from each of the delivery and return pipelines.

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Preferably the apparatus includes at least one valve on each side of the pig trap and in series with the pig trap and the pig transfer piping loop.

Preferably the pig capture and transfer apparatus includes a pressure relieving means arranged to place a downstream region of the pig trap or trapping means in direct or indirect fluid communication with the delivery bypass pipe.

More preferably the pressure relieving means includes flow restricting means such as a one way valve which permits flow through the pressure relieving means away from the downstream region but at least substantially prevents flow into the downstream region of the pig trap.

An outlet of the pressure relieving means may be in fluid communication with the return and delivery bypass pipes.

The apparatus preferably includes control means for controlling the capture of the pig and the transferring of the pig from the delivery to the return pipeline. The control means preferably comprises electronic control means situated at the host facility.

When complete isolation of the return pipeline from the first fluid is required, the apparatus preferably comprises flushing means for injecting a flushing fluid to flush the first fluid out of the pig trap and also possibly out of the or each bypass pipe. This means may be arranged to flush first fluid from these apparatus elements back into the delivery pipeline and the flushing fluid may comprise either the second fluid or a further

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fluid supplied via a flushing fluid injection means.

The manner in which prior art round trip pigging is effected will be described with reference to the accompanying Figures 1 and 2 and an embodiment of the invention will be described by way example only with reference to Figures 3 to 7.

In the accompanying schematic Figures:

Figure 1 shows a existing system for round trip pigging prior to a pigging operation;

Figure 2 shows the system of Figure 1 during a pigging operation;

Figure 3 shows a system according to the invention prior to a pigging operation;

Figures 4 to 6 show the system of Figure 3 at various stages of a pigging operation; and

Figure 7 shows details of the pig trap of the system shown in Figures 3 to 6.

In the Figures open valves are shown unshaded (e.g. valve 112 in Figure 1) and closed valves are shown shaded (e.g. valves 122 in Figure 1).

A prior art round trip pigging operation will first be described with references to Figures 1 and 2.

A host facility 101 is connected to a remote location 102 by a delivery pipeline 104 containing a delivery valve 112 and a return pipeline 106 containing a return valve 114. The host facility 101 may be a floating oil rig and has a pig launcher arrangement 108 loaded with a pig 124 and a

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pig receiver arrangement 110. Remote portions 104a and 106a of the delivery and return pipelines respectively may be connected to oil wells and, during normal production, water is pumped down the delivery pipeline 104 to the well to assist in pressuring the oil or gas reservoir. Oil or gas from the production well enters the return pipeline 106 and passes therethrough to the host facility 101. At the remote location 102 a pig piping loop 120 with loop valves 122 connects a delivery pipeline junction 116 with a return pipeline junction 118. During normal production, the loop valves 122 are closed and the transfer and return pipeline valves 112 and 114 are both open permitting water to be pumped to the well through the delivery pipeline 104 and oil to be returned from the well to the host facility 101 through the return pipeline 106. When there is a requirement to propel the pig 124 through the delivery or return pipelines 104 and 106, the delivery and return valves 112 and 114 are closed, as shown in Figure 2, the loop valves 122 are opened and the pig 124 is launched into the delivery pipeline 104. The flow of water normally delivered by the delivery pipeline 104 to the well then carries the pig 124 down the delivery pipeline 104, round the pig piping loop 120 and into and up the return pipeline 106. Eventually the pig 124 arrives back at the host facility 101 where it is captured by the pig receiver arrangement 110.

During the entire pigging operation, the well is shut in because the delivery and return valves 112 and 114 are closed. Subsequent restarting of the production well or wells can be difficult. The return pipeline is completely filled with water by the operation and at the end of the operation the pig is being propelled over a distance of

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pipeline approximately equal to twice the distance between the host facility and the remote location which can cause problems. At the end of the pigging operation, the valves are switched back to the configuration shown in Figure 1 and an attempt is made to resume normal operation. A large amount of water has to be removed from the return pipeline 106. Furthermore, if the delivery pipeline 104 is used to deliver gas to the well, to effect gas lifting of the oil from the well, undesirable chemical reactions may occur if the gas lift gas is allowed to enter the return pipeline 106.

An embodiment of the invention will now be described with reference to Figures 3 to 7 in which parts which correspond to like parts in the prior art arrangement shown in Figures 1 and 2 are referenced with numbers 100 less than those used Figures 1 and 2 for the corresponding part and are not described in detail below.

The pig launcher arrangement 8 of the host facility 1 includes a pig launching bypass loop 26 in which a pig launcher vessel 28 and pig launch valves 30 and 31 are situated. The delivery pipeline 4 has a pig launch diversion valve 32 situated upstream of an outlet end of the pig launching bypass loop 26.

The pig receiver arrangement 10 at the host facility 1 includes a pig receiver bypass loop 34 in which a pig receiver vessel 36 and pig receiver valves 38 and 39 are situated. The return pipeline 6 has a pig receiver diversion valve 40 situated downstream of an inlet end of the pig receiver bypass loop 34.

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The pig transfer pipeline 20 at the remote location 2 includes a pig trap 42 comprising a chamber large enough to accommodate the pig 24 connected in series with the pig transfer pipeline 20. Between the pig trap 42 and the delivery and return pipeline junctions 16 and 18 pig trap entry and exit isolation valves 44 and 46 are respectively situated. The use of two of each valve provides excellent isolation of the pig trap 42, however only one of each may be employed. The isolation valves 44 and 46 are preferably situated close to the pig trap 42.

Bypass piping means 48 connects the delivery and return pipelines 4 and 6 with the pig trap 42. The bypass piping means includes a delivery bypass pipe 50 with an outlet 52 connected to the delivery pipeline 4 downstream of the delivery valve 12 and two delivery bypass valves 54 (only one may be employed) and return bypass pipe 56 with an inlet 58 connected to the return pipeline 6 upstream of the return pipeline valve 14 and two return bypass valves 60 (only one may be employed). The bypass pipes 50 and 56 are connected in series by a T-junction 62 from which a branch pipe 64 extends to the pig trap 42 where it is preferably connected to the pig trap 42.

The pig trap 42 and associated system parts are shown in greater detail in Figure 7. The pig trap 42 has an inner passage 68 dimensioned to slidably receive the pig 24 such that flow between the pig and the wall of the inner passage is substantially prevented. The branch pipe 64 is in fluid communication with an upstream region 70 of the pig trap and a pressure relieving pipe 72 places a downstream region 76 of the pig trap in communication with the branch pipe 64. A one way check valve 74 is situated

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in the pressure relieving pipe 72 which permits fluid to flow from the downstream region 76 to the branch pipe 64 but prevents flow in the reverse direction.

A flushing fluid injection point 66 may be provided between the pig trap 42 and the pig trap entry isolation valves 44 for delivering a flushing fluid from an injection line (not shown) into the pig trap 42 and pig transfer piping loop 20.

A complete pigging sequence will now be described starting and finishing with normal oil well production with reference to Figures 3 to 7.

Figure 3 shows normal production occurring. The pig launch valves 30 and 31 are closed and the pig launch diversion valve 32 is open so that water can be pumped down the delivery pipeline 4 to the remote location where all valves except the delivery valve 12 and return valve 14 are closed. Injection water is accordingly routed through the delivery pipeline junction 16 and on through section 4a of the delivery pipeline leading to the well where it is injected into the well.

Oil coming from the well is delivered to the remote location by means of section 6a of the return pipeline then through the return pipeline junction 18 and up the return pipeline 6 to the host facility. Since the pig receiver valves 38 and 39 are closed and the pig receiver diversion valve 40 is open, the oil is not diverted through the pig receiver bypass loop 34.

When there is a requirement to effect pigging of the

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delivery and/or return pipelines 4 and 6 with the pig 24, the valves are changed to the configuration shown in Figure 4 by control means (not shown and possibly based on the host facility).

The pig launch diversion valve 32 is closed and the pig launch valves 30 and 31 are opened. This diverts water through the pig launching bypass loop 26 and the pig launcher vessel 28 so that the pig 24 is propelled therefrom down the delivery pipeline 4. Since the delivery valve 12 is closed and the pig trap entry isolation valves 44 and delivery bypass valves 54 are open, water from the delivery pipeline 4 is diverted therefrom at the delivery bypass junction 16 into the pig trap 42 via a first part of the pig transfer piping loop 20, through the branch pipe 64 and via the delivery bypass pipe 50 to the part 4a of the delivery pipeline leading to the well.

Once the pig 24 reaches the pig trap 42 it is retained there because the pig trap is dimensioned to prevent the pig from turning, so it cannot enter either the branch pipeline 64 or the pressure relieving pipe 72.

With reference to Figure 7, the pig 24 enters the pig trap 42 in the direction of arrow A and its leading end 78 passes the entrance 80 to the branch pipe 64. Continued movement of the pig 24 in the direction of arrow A into the position shown in Figure 7 is possible because of the pressure relieving pipe 72 which permits further pressurised water to enter the pig trap through the pig trap entry isolation valves 44 and force water in the downstream region 76 of the pig trap into the branch pipe

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64 through the pressure relieving pipe 72 and its associated one way valve 74 in the direction of arrow D. The water then flows away from the pig trap along the branch pipe 64 in the direction of arrow C.

A sensing means associated with the pig trap 42 and possibly upstream thereof sends a signal to the host facility to indicate that the pig 24 has been captured by the pig trap 42 and the valves are then changed to the configuration shown in Figure 5.

The pig launch valves 30 and 31 are closed and the pig launch diversion valve 32 is opened so that water is no longer diverted through the pig launching bypass loop 26. The pig trap entry isolation valves 44 and delivery bypass valves 54 are closed and the delivery valve 12 is opened so that normal flow of water through the delivery pipeline 4 is re-established, i.e. without diversion through the pig trap 42 and the delivery bypass pipe 50.

The valves are then changed to the configuration shown in Figure 6. The return valve 14 is closed and the pig trap exit isolation valves 46 and return bypass valves 60 are opened. Accordingly, oil reaching the remote location 2 from the well along the portion 6a of the return pipeline is diverted through the return bypass pipe 56 and the branch pipe 64 into the pig trap 42. As this occurs, oil flows into the upstream region 70 of the pig trap 42 through the branch pipe 64 in the direction of arrow B. Since the oil cannot flow in the opposite direction to arrow D through the one way 74 it forces the pig 24 out of the pig trap 42 through the pig trap exit isolation valves 46. The pig 24 is then propelled by the oil through the

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pig transfer piping loop 20 and into the return pipeline 6 via the return pipeline junction 18. Thereafter, the pig is propelled up the return pipeline by oil passing through the return bypass pipeline 56 and the pig transfer piping loop 20 back to the host facility 1 where the pig receiver diversion valve 40 is in a closed state and the pig receiver valves 38 and 39 are in an open state so that oil is diverted through the pig receiver bypass loop 34 containing the pig receiver vessel 36 in which the pig 24 is captured.

Once pig capture at the host facility has been completed, the valves are changed back to the configuration shown in Figure 3, so that all the isolation valves 44 and 46, the bypass valves 54 and 60 and the pig receiver valves 38 and 39 are closed and the return valve 14 and the pig receiver diversion valve 40 are opened. This results in normal flow through the return pipeline 6 being re-established, i.e. not through the return bypass pipe 56, the pig transfer piping loop 20 and the pig receiver bypass loop 34.

The pig 24 can then be retrieved from the pig receiver vessel 36.

Throughout the entire pigging operation described above, flow of water to the well through the delivery pipeline 4 and oil to the host facility 1 through the return pipeline 6 are substantially if not completely not interrupted and normal well production accordingly does not have be affected in any way.

If it is important that not even any traces of fluid

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delivered by the delivery pipeline 4 enter the return pipeline 6, a flushing fluid injection point 66 may be provided between the pig trap entry isolation valves 44 and the pig trap 42 for supplying flushing fluid from a suitable supply (not shown) for example provided directly from the host facility. Such flushing would be effected as an additional stage between those shown in Figures 5 and 6. From the arrangement shown in Figure 5, the delivery bypass valves 54 would be opened and an appropriate fluid (e.g. methanol) would be injected from the injection point 66 thus flushing the interior of the pig trap 42 into the part 4a of the delivery pipeline 4. Upon completion of flushing, the delivery bypass valves 54 would be closed to return to the configuration shown in Figure 5 and then the pigging operation would be continued by progressing to the configurations shown in Figures 6 and 3 as described above.

While a particular apparatus and method have been described, it will be appreciated that variations could be effected without departing from the scope of the invention. For example, if interruption of the flow through the delivery pipeline 4 only could be tolerated, then an alternative arrangement could be used in which the return bypass pipe 56 was connected to a pig trap situated in the location occupied by the delivery pipeline junction 16 and an extra valve was provided immediately upstream of the pig trap.

When the pig is being propelled along a pipeline by gas passing therethrough, the gas flow rate may be reduced by appropriate throttle valves or other means to ensure that the pig is not propelled at above its maximum designed

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velocity. In such a situation, fluid flows to and/or from the well will be affected but not interrupted.

While the invention has been described in the context of a sub-sea hydrocarbon field it would be equally applicable to any hydrocarbon field in which there is a requirement to pig a pipeline extending between a host facility and a remote location which is difficult to access, for example a swampy or marshy area.

Despite the fact that the pipe 20 through which the pig passes in transit between the delivery and return pipelines is described as a loop it will have any required shape which will be determined by the juxtapositions of the delivery and return pipelines.

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CLAIMS:

1. A method of pigging a pipeline network (4, 6) connecting a host facility (1) to a remote location (2), the pipeline network including a delivery pipeline (4) for transporting a first fluid from the host facility (1) to the remote location (2) and a return pipeline (6) for transporting a second fluid from the remote location (2) to the host facility (1), the method comprising the steps of:

- (i) propelling a pig (24) along the delivery pipeline (4) from the host facility (1) to the remote location (2) by means of the first fluid;
- (ii) transferring the pig (24) to the return pipeline (6); and
- (iii) propelling the pig (24) along the return pipeline (6) from the remote location (2) to the host facility (1) characterised in that
- (iv) transferring the pig (24) to the return pipeline (6) involves capturing the pig (24) in a pig capture and transfer means situated at the remote location (2); and
- (v) propelling the pig (24) along the return pipeline (6) by means of the second fluid.

2. The method according to claim 1 wherein flows of the first and second fluids are substantially uninterrupted.

3. The method according to claim 1 or 2 wherein transferring the pig (24) to the return pipeline (6) is effected by means of the second fluid.

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4. The method according to claim 1, 2 or 3 wherein transferring the pig (24) to the return pipeline is effected via a pig transfer pipe (20).
5. The method according to claims 3 and 4 wherein the flow of the second fluid is diverted from the return pipeline (6a) via a return by-pass pipe (56) to propel the pig (24) through the pig transfer pipe (20).
6. The method according to claim 5 wherein an inlet (58) of the return by-pass pipe (56) is connected to the return pipeline (6a) at a location upstream of a junction (18) between the return pipeline (6) and the pig transfer pipe (20).
7. The method according to any preceding claim wherein capturing the pig (24) involves capturing it in a pig trap (42) in series connection with a pig transfer pipe (20) connecting the delivery and return pipelines (4, 6).
8. The method according to claim 7 wherein capturing the pig in the pig trap (42) includes diverting a flow of the first fluid through the pig trap (42).
9. The method according to claim 8 wherein diversion of the flow of the first fluid through the pig trap (42) involves passing a flow of the first fluid through a delivery by-pass pipe (50) with an outlet (52) connected to the delivery pipeline (4a) at a location downstream of a junction (16) between the delivery pipe (4) and the pig transfer pipe (20).
10. The method according to any preceding claim including

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supplying flushing fluid to flush the first fluid from around the pig (24) after its capture at the remote location (2).

11. Pipeline pig capture and transfer apparatus for installation at a location (2) remote from a host facility (1) for capturing a pig (24) delivered to the remote location (2) from the host facility through a delivery pipeline (4) and transferring the pig (24) to a return pipeline (6) for delivery therethrough back to the host facility (1), the apparatus including a pig transfer pipe (20) connecting a delivery pipeline junction (16) with a return pipeline junction (18), and a return by-pass pipe (56) connected to divert a flow of a fluid from the return pipeline (6a) for propelling the pig (24) through the pig transfer pipe (20) into the return pipeline (6).
12. The apparatus according to claim 11 wherein an inlet (58) of the return by-pass pipe (56) is connected to the return pipeline (6a) at a location upstream of a junction (18) between the return pipeline (6) and the pig transfer pipe (20).
13. The apparatus according to claim 11 or 12 including a pig trap (42) in series connection with the pig transfer pipe (20).
14. The apparatus according to claim 11 or 12 and claim 13 wherein an outlet of the return by-pass pipe (56) is connected to an upstream region of the pig trap (42).

15. The apparatus according to claim 13 further including means (50, 54) for diverting a flow of a first fluid from

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the delivery pipeline (4) through the pig trap (42) and back into the delivery pipeline (4a).

16. The apparatus according to claim 13 or any claim depending thereon including at least one valve (44, 46) on each side of the pig trap (42) and in series connection with the pig trap (42) and the pig transfer pipe (20).

17. The apparatus according to any one of claims 11 to 16 further including flushing means (66) adapted to supply a flushing fluid to the pig trap (42) to flush fluid out of the pig trap (42).

18. The apparatus according to any one of claims 11 to 17 including control means for controlling the capture of the pig (24) and the transferring of the pig (24) from the delivery pipeline (4) to the return pipeline (6).

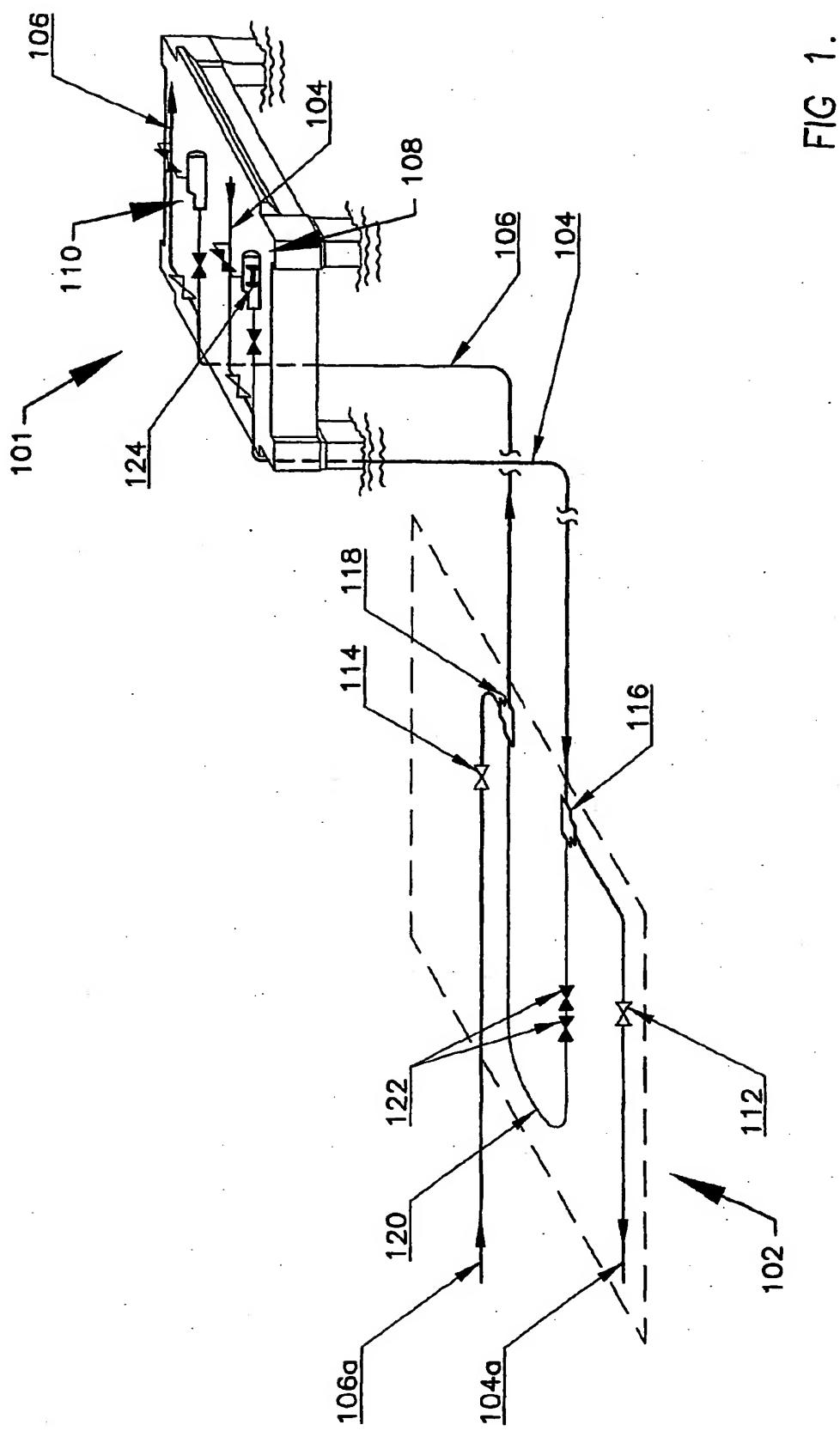


FIG. 1.

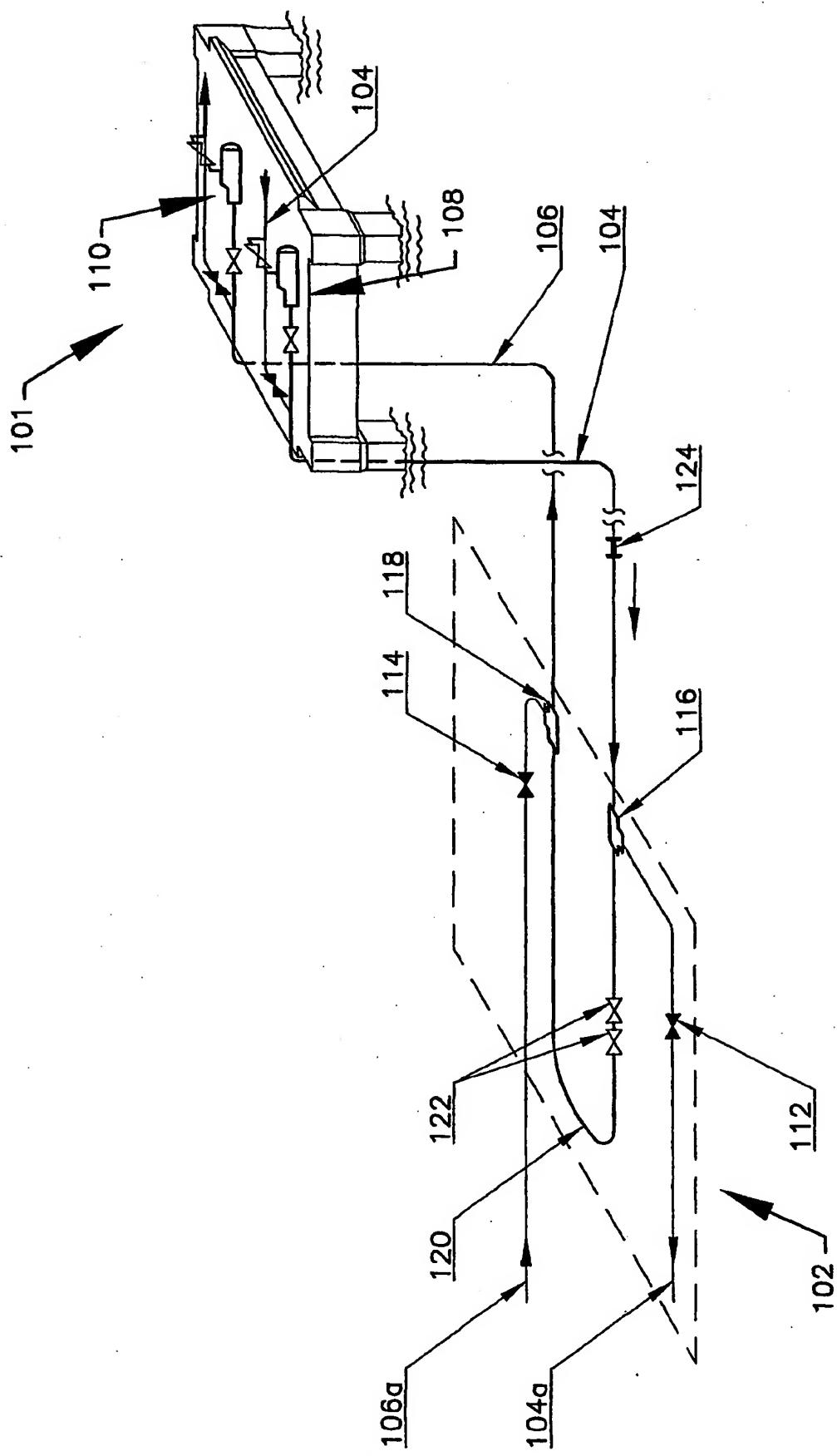
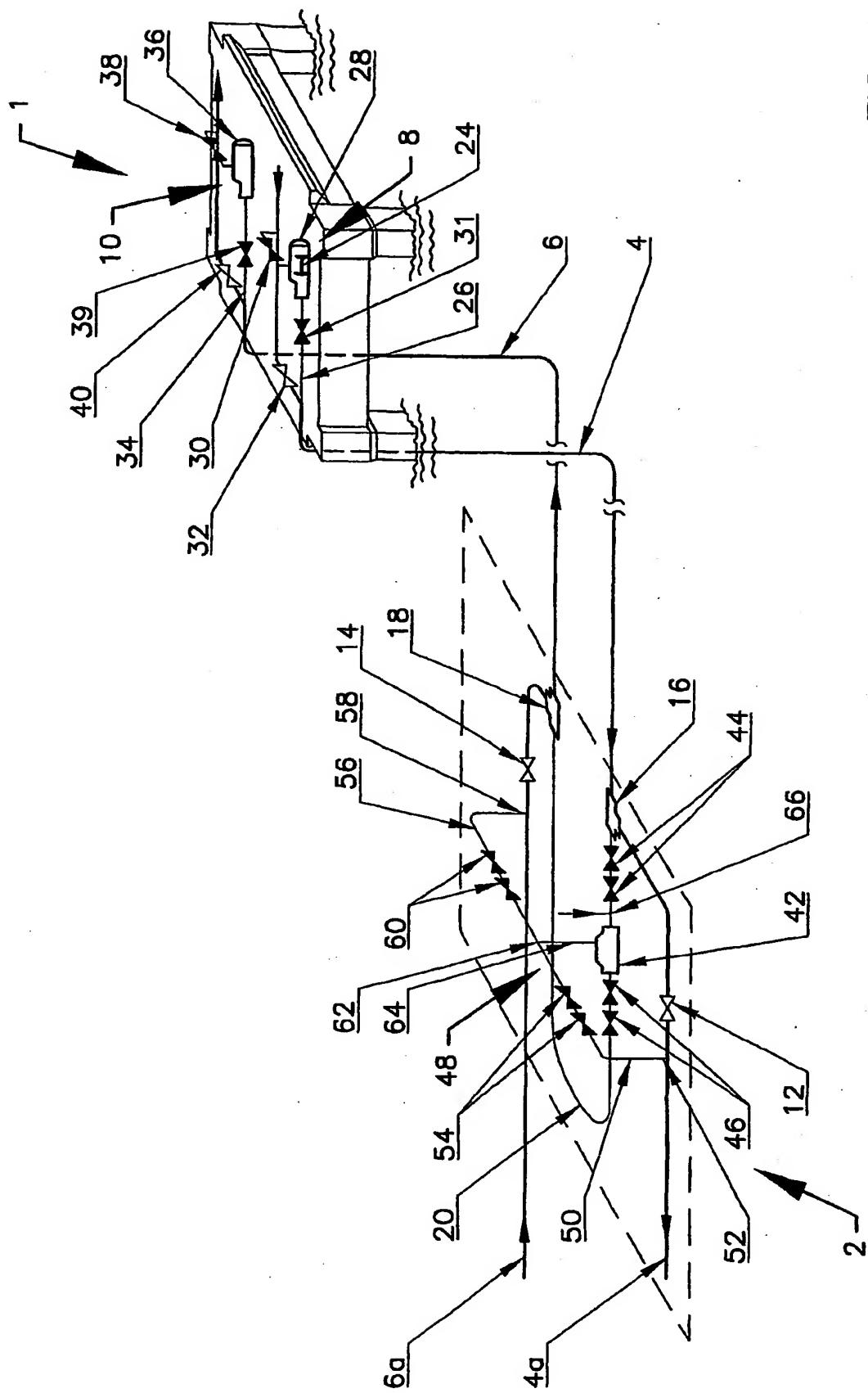


FIG 2.

FIG 3.



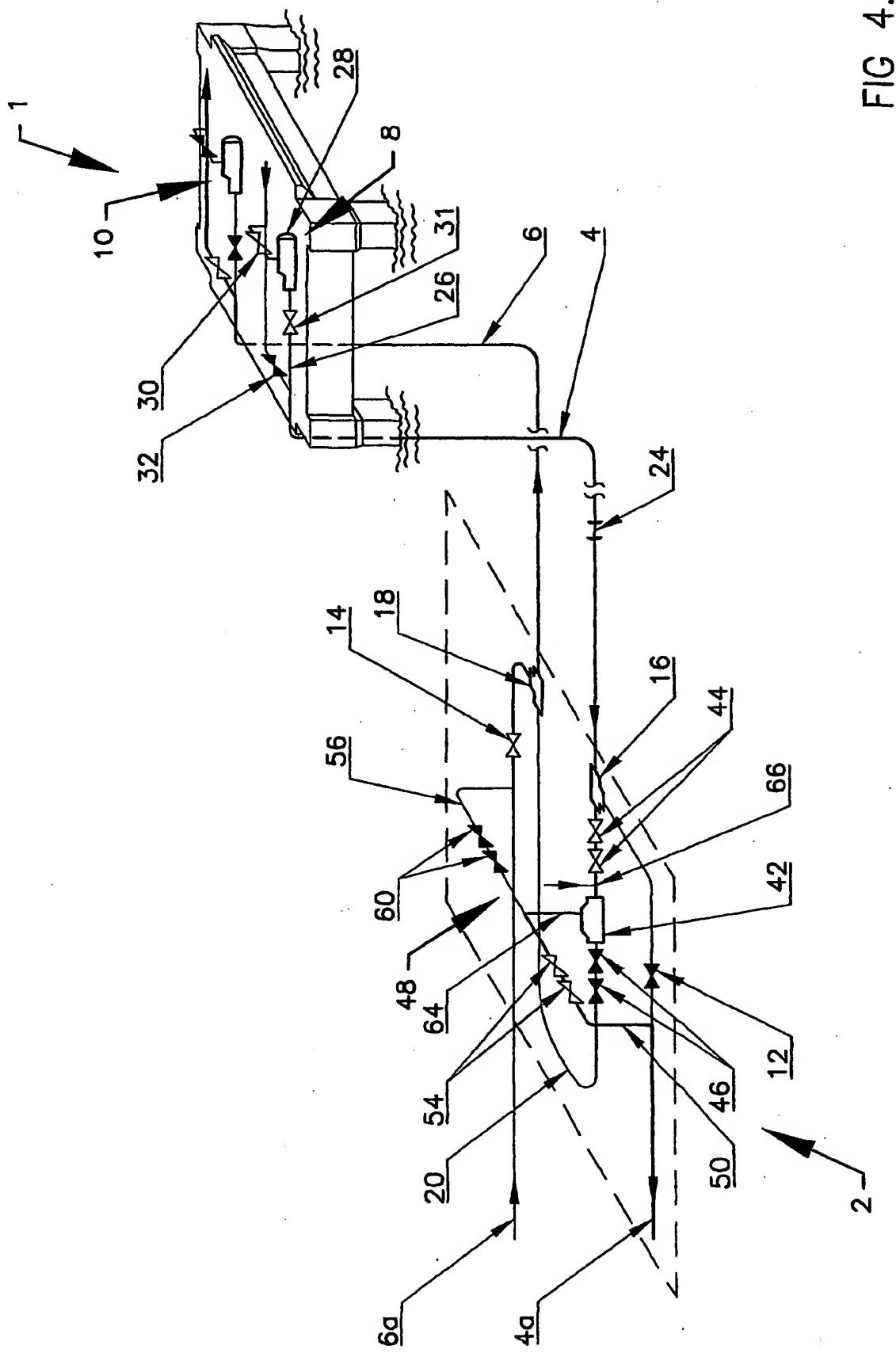


FIG 4.

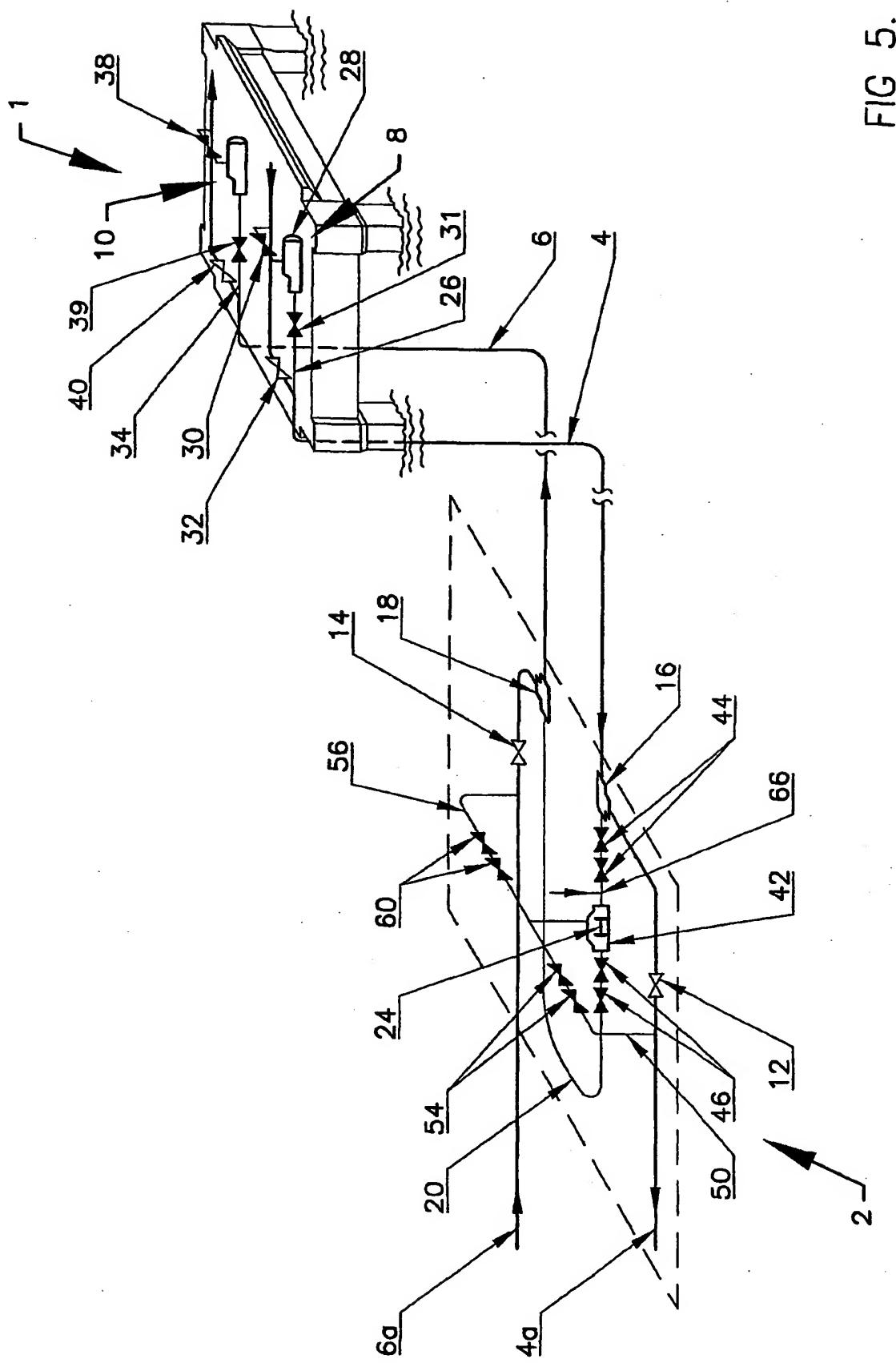


FIG 5.

FIG 6.

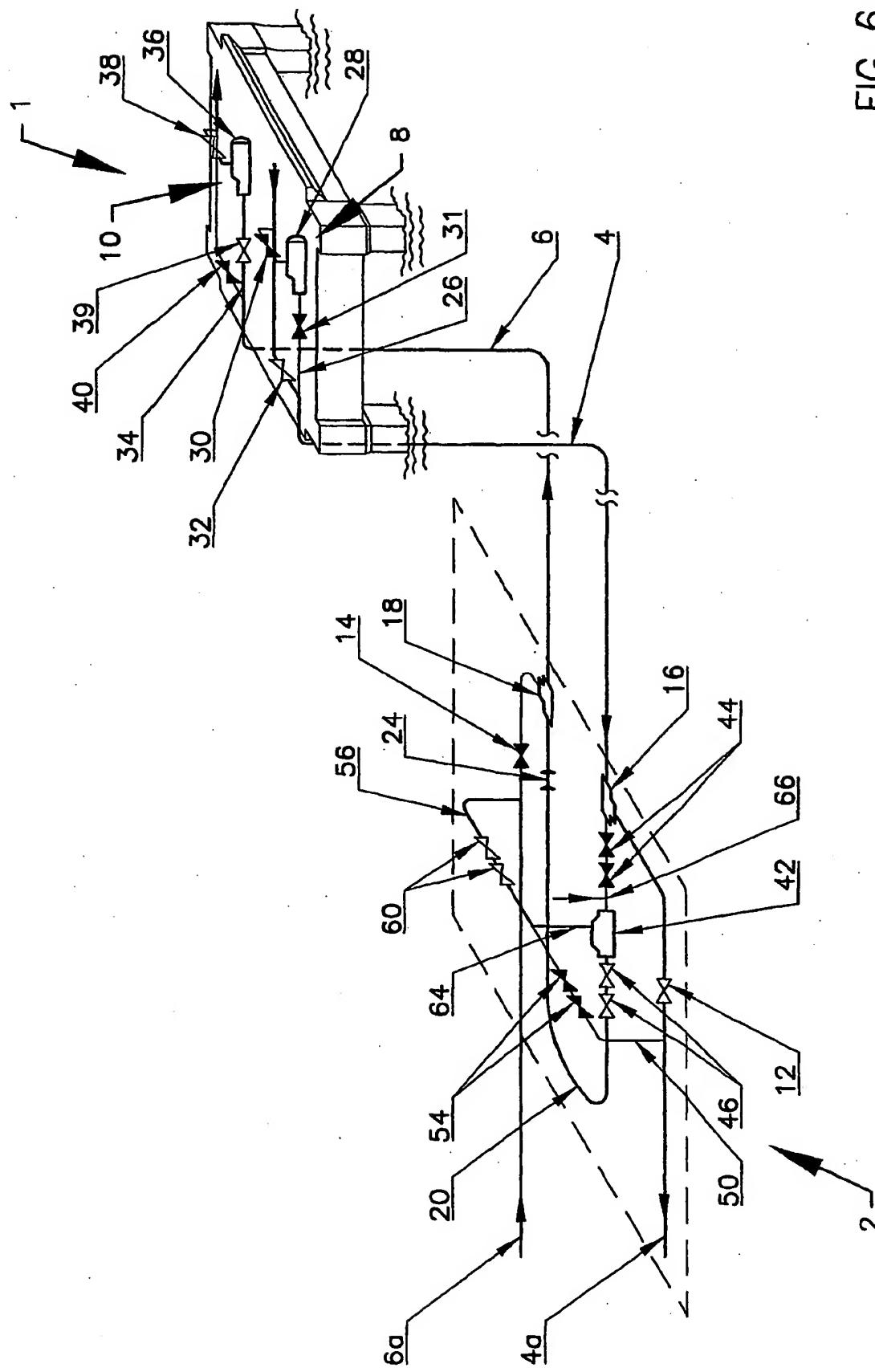


FIG 7.

